DIOXIN-LIKE COMPOUNDS IN TRANSFORMER OIL
AN EVALUATION OF THEIR POTENTIAL IMPACT ON SOIL CLEANUP STRATEGIES AT RFETS

Like many industrial sites, at the Rocky Flats Environmental Technology Site (RFETS), polychlorinated biphenyl (PCB) contamination of soil exists at electrical transformer sites as a result of equipment leaks and the release of transformer oil Some of these sites were remediated to achieve a Toxic Substances Control Act (TSCA)-based cleanup goal of 25 parts per million (ppm) total concentration of all Aroclors [1] Most of the sites were cleaned up to less than 10 ppm Recently, there has been much toxicological research pertaining to dioxins and other compounds with dioxin-like properties Although Aroclors do not contain dioxins, they do contain a few PCBs with dioxin-like properties

The purpose of this paper is to evaluate whether cleanup of PCB-contaminated soil at a transformer site to less than 10 ppm Aroclor is sufficiently protective to render the site No Further Accelerated Action (NFAA) in light of recent studies showing that a few PCBs have dioxin-like properties Other transformer sites at RFETS are still under investigation, and if necessary, the soil will be cleaned up to achieve the Rocky Flats Cleanup Agreement (RFCA) Wildlife Refuge Worker (WRW) soil Action Level (AL) for Aroclor of 12 4 ppm[2] (DOE, CDPHE, EPA 2003) Therefore, this evaluation will also serve to evaluate the protectiveness of the WRW AL for future cleanups Lastly, this paper also addresses the weathering of Aroclors in soil, which may alter the concentrations of the PCBs they contain, and thus alter the apparent toxicity of the contaminated soil

Polychlorinated Biphenyls

A PCB is an organic compound consisting of a biphenyl (two 6-carbon benzene rings linked by a single carbon-carbon-bond) with anywhere from one to 10 chlorine atoms attached to the carbons of the benzene rings (2 of the twelve carbons on the benzene rings are unavailable for chlorine substitution (hydrogen replacement) because they form the single carbon-carbon bond connecting the rings) There are 209 combinations of the number of chlorine atoms and their positions on the benzene rings Each of these combinations is a unique compound known as PCB congener Each congener has a unique number (from 1 to 209) known as a Ballschmiter and Zell (BZ) Number The numbering starts with the mono-chlorinated PCB congeners and ends with the deca-chlorinated PCB congener A summary of the congeners is shown in Table 1

Commercially produced PCBs were mixtures of these congeners Monsanto Corporation marketed mixtures of PCBs as Aroclors The Aroclor is identified with a 4 digit code, the first two digits referring to the type of mixture, and the last two digits referring to the approximate chlorine content by weight percent (The exception to this code is for Aroclor 1016 which has a 41% chlorine content) As can be seen from Table 2, for the Aroclor 12- series, the greater the chlorine content, the greater the fraction of higher chlorinated congeners (higher BZ Numbers) The weight percentage of each of the 209 congeners in the PCB mixtures are shown in Table 3 (EPA 2003a)

Dioxins and Dioxin-Like Compounds

Dioxins are present in the environment primarily because they are products of the combustion of chlorine-containing organic material They are also formed as byproducts in the bleaching of paper pulp and in the manufacturing of certain chemicals, e g , herbicides and pesticides Dioxins are a class of compounds that are of potential human health concern because they may pose an increased risk of cancer at extremely low levels of exposure The most toxic member of the class is *2,3,7,8*-tetrachlorodibenzo-*para*-dioxin (TCDD) Several other polychlorinated dibenzodioxins (PCDDs) as well as some polychlorinated dibenzofurans (PCDFs) and PCBs also display TCDD-like toxicity due to their structural similarity to TCDD There are

[1] Monsanto Corporation marketed transformer oil containing PCBs by the trade name "Aroclor"
[2] The WRW AL of 12 4 ppm is for Aroclors 1221, 1232, 1242, 1248, 1254, and 1260 Aroclor 1016 has an AL of 46 4 ppm

1/15

29 TCDD-like compounds (out of a total of 419 different polychlorinated dioxins, furans and biphenyls) that are particularly toxic Twelve of these TCDD-like compounds are PCB congeners

Risk Evaluation of Dioxins and Dioxin-Like Compounds

PCBs are probable human carcinogens, and the WRW AL is based on the cancer slope factor determined for Aroclors as published in the Integrated Risk Information System (IRIS) In principle, the development of an AL based on the cancer slope factor for the Aroclor should capture the carcinogenicity of the TCDD-like PCB congeners present in the Aroclor This can be validated by applying the approach developed by the Environmental Protection Agency (EPA) Superfund Program that examines the concentration and toxicity of dioxins, furans, and PCB congeners

Screening level evaluations of TCDD-like compounds in soil are performed by calculating the concentration of TCDD Equivalents (TEQ) in the soil, which is the Toxicity Equivalency Factor (TEF) weighted sum of the 29 TCDD-like compound concentrations (EPA 1998) The TEF is the fractional toxicity of the TCDD-like compound to that of TCDD, e g , a TEF of 0 1 indicates the compound is one-tenth as toxic as TCDD TEQ is calcuated as

$$\text{TEQ (total)} = \Sigma\,(C_i \times \text{TEF}_i)$$

where C_i is the concentration of the ith TCDD-like compound in the soil in parts per trillion (ppt)

The USEPA Superfund Program establishes a TEQ of 1000 ppt as a level that is not of a cancer or non-cancer concern for lifetime exposure of residents A value of 5,000 – 20,000 ppt is the screening value used for industrial or commercial land uses (EPA 1998)

As mentioned, 12 of the PCB congeners have TCDD-like toxic properties They are as listed in Table 4 with their associated TEFs (EPA 2003b)

Given the weight fractions shown in Table 3 for these congeners in the various Aroclor mixtures, the TEQ associated with an Aroclor concentration in the soil can be computed For illustration purposes, an Aroclor concentration of 10 ppm was chosen to compute the TEQs of the various Aroclor mixtures because the transformer sites that have been cleaned up were remediated to concentrations less than 10 ppm Also, the sites that are yet to be cleaned up, will be remediated to achieve the WRW AL of 12 4 ppm (a similar level)

As shown in Table 5, the maximum TEQ for soil with a 10 ppm Aroclor concentration is 512 parts per trillion (for Aroclor 1254a) This is approximately one-half the level that is of concern to EPA for a residential land use Because there would be significantly less human exposure to soil at a wildlife refuge compared to a residential setting, the calculated TEQ demonstrates that the TCDD-like toxicity of the congeners in a PCB mixture is not an important consideration in cleanup of the PCB contaminated sites at RFETS

Weathering and Chemical Analysis

Once introduced into the environment, PCBs undergo weathering, which alters the distribution of the congeners present in the Aroclor that was released The weathering action is one of dissolution in water, volatilization, adsorption on to soil or sediment, photolytic or biologically-mediated dechlorination, and biodegradation The weathering can affect the identification of Aroclors during chemical analysis, and may also alter the apparent toxicity of the Aroclors

Weathering

As mentioned, once introduced into the environment, weathering can alter the relative proportions of congeners present in the original Aroclor The degree of weathering will be dependent on the local conditions For example, at the Hudson River Superfund Site, one of the more PCB-contaminated sites in the country, dissolution in water, volatilization, adsorption on to river sediment, photolytic or biologically-mediated dechlorination, biodegradation, and even bioaccumulation in the food chain may all be significant factors altering the congener composition of the original Aroclors that were released This is due to the complexities of the aquatic environment where the PCBs were released, e g , saturated sediments, constant exchange of interstitial sediment water, aerobic and anaerobic conditions in the sediments, sediment erosion, light penetration through the water column, and the presence of a complex food chain As discussed below, in the semi-arid shallow soil at RFETS, such weathering processes would not be expected to be significant

PCBs are relatively non-soluble and non-volatile Because the soil at the transformer sites is dry most of the time, dissolution would not be a significant process In general, the higher the degree of chlorination, the less volatile the PCB congener At RFETS, the Aroclors with more highly chlorinated congeners were largely used, e g , Aroclors 1254 and 1260 Therefore, volatilization is not likely to be significant

In general, the more highly chlorinated congeners are the most susceptible to photolysis The products of photolysis are less chlorinated congeners, some of which are the congeners with TCDD-like properties For example, photolysis of Aroclor 1254 resulted in significant dechlorination of PCB congerers 114, 156, and 157, with the formation of the PCB congeners 77 and 126 which were not detected in the original unirradiated mixture (EPA 2000) The PCB congeners 114, 156, and 157 represent less than 2-3 percent by weight of Aroclor 1254 (see Table 1), and the PCB congners 77 and 126 in the irradiated Aroclor 1254 sample were only 2 5% and 0 43% by weight Therefore, the resulting irradiated mixture would still be "fingerprinted" as Aroclor 1254 However, the presence of congener 126 now renders the irradiated Aroclor 1254 mixture more toxic (congener 126 has a TEF = 0 1) For the transformer sites at RFETS, photolysis is not a significant mechanisms that would alter the PCB congeners present in the shallow soils Photolysis, if occurring, would only be active at the very surface of the soil and not affect non-irradiated underlying PCB contaminated soil where the greater mass of the contamination lies

Biological dechlorination of PCB congeners has been demonstrated under anaerobic conditions (EPA 2000) This biologically-mediated dechlorination was observed primarily for PCB congeners with 4 or less chlorine atoms There are no PCB congeners with dioxin-like properties with less than 4 chlorine atoms Consequently, this dechlorination process is not capable of increasing the toxicity of soil contaminated with PCBs at any site For the transformer sites at RFETS, biologically-mediated dechlorination is not even likely to occur because the near surface soils should be largely under aerobic conditions

As mentioned, aerobic and anaerobic biodegradation of PCBs has been demonstrated (EPA 2000) However, unlike dechlorination, this type of degradation results in cleavage of the biphenyl rings, thus destroying the PCB If active in soil at the PCB sites, this will result in a decrease in PCB concentrations over time

It is concluded that, although photolysis may produce PCB congeners with dioxin like properties that are either not present in the original PCB mixture or are now at a higher concentration, the mechanism is not significant for soil at the PCB sites Biologically-mediated dechlorination would not likely be occurring in the shallow soils which are largely under aerobic conditions, and if it were occurring, it would not increase the toxicity of the PCB contaminated soil Aerobic biodegradation of the PCB congeners may be occurring, which would serve to reduce the concentrations of the PCB congeners over time

Chemical Analysis

SW-846 Method 8082 is used for PCB analysis at RFETS It is a gas chromatographic method were the PCB mixture (Aroclor) is identified by comparing the chromatogram of the sample to various Aroclor standard chromatograms, and determining the best visual fit The heights of the 3 –5 major peaks in the standard chromatogram are compared to those in the sample to determine the concentration

Method 8082 mentions the effect of weathering on PCB analysis, i e , that weathering can alter the relative proportions of congeners present in the sample to the extent that the chromatogram pattern for the sample is not clearly recognizable as one of the original Aroclors When sampling and analysis is conducted for

3

regulatory compliance on the basis of Aroclor concentrations, the Aroclor is identified as the one with a chromatogram most similar to that of the sample This methodology is appropriate for RFETS because the transformer sites that have been cleaned up were remediated to achieve a TSCA-based standard for Aroclors Also, for transformer sites that may require cleanup in the future, the remediation goal will be the WRW AL, which was computed for the Aroclor mixtures

If quantitation of specific congeners is required, standards for the congeners of interest are required to evaluate the chromatograms The more congeners to be quantified, the more costly the analysis However, as discussed in this paper, characterization of transformer sites at RFETS using a congener-specific method is not required because the congener distributions are not expected to be significantly different from those in the original Aroclors

Presence of Dixoins and Furans in PCB Mixtures

Furans are produced during the combustion of PCBs, however, they are also present in the PCB mixtures as a byproduct of commercial production (ATSDR 2000) Dioxins are not present in PCB mixtures

Although furans are present in PCB mixtures, they are at very low concentrations that do not pose adverse health effects when PCB contaminated soils are cleaned up to meet regulatory limits Table 6 shows the concentrations of furans in the PCB mixtures (Aroclors) As can be seen, tetra-, penta-, and hexa-chlorinated dibenzofurans are present in various concentrations in the PCB mixtures The highest concentration of the summed chlorinated dibenzofurans is 5 6 ppm, or 0 00056% A site cleaned up to 10 ppm PCBs would have a maximum concentration of chlorinated dibenzofurans of 000056 ppm, or 56 ppt Conservatively applying the TEF for the most toxic chlorinated dibenzofuran (0 5 for 2,3,4,7,8-PeCDF) to this concentration provides a TEQ of 28 ppt, an insignificant concentration relative to EPA's 1,000 ppt screening value

Conclusions

The evaluation presented in this paper demonstrates that the past cleanup of the transformer sites at RFETS to achieve Aroclor levels less than 10 ppm, and the future cleanup of transformer sites to achieve the WRW AL of 12 4 ppm adequately protects human health Although TCDD-like compounds are present in the Aroclors release to soil, the evaluation demonstrates that

1 The health risk posed by the TCDD-like compounds is not a concern at these cleanup levels,
2 Weathering of the Aroclors released to the soil is unlikely to significantly alter the congener distribution or the toxicity of the Aroclors, and
3 Congener-specific PCB analysis of soil samples, or analysis for dioxins and furans, is not required for characterizing transformer sites at RFETS

References

ATSDR, 2000 *Toxicological Profile for Polychlorinated Biphenyls (PCBs),* U S Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, November, 2000

DOE, CDPHE, EPA, 2003 *Modifications to the Rocky Flats Cleanup Agreement Attachment*, U S Department of Energy, Colorado Department of Public Health and Environment, and U S Environmental Protection Agency, Rocky Flats Environmental Technology Site, Golden, Colorado, June

EPA 1998 *Approach for Addressing Dioxins in Soil at CERCLA and RCRA Sites*, OSWER Directive 9200 4-26 Memo from Timothy Fields Jr , April 13, 1998

EPA, 2003a *PCB ID – Congener Specific PCB (Aroclor) Composition Data*, US EPA National Center for Environmental Assessment (htttp //www epa gov/toxteam/pcbid/aroclor_comp_frame htm)

4

Table 1 PCB Congeners

# of Chlorine Substitutions	# of PCB Congeners	Congener BZ Numbers
1	3	1-3
2	12	4-15
3	24	16-39
4	42	40-81
5	46	82-127
6	42	128-169
7	24	170-193
8	12	194-205
9	3	206-208
10	1	209

6

Table 2 Approximate Weight Percent of Congeners in some Aroclors

BZ #s	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248
1-3	0 70	60 06	27 55	0 75	0 07
4-15	17 53	33 38	26 83	15 04	1 55
16-39	54 67	4 22	25 64	44 91	21 27
40-81	22 07	1 15	10 58	20 16	32 77
82-127	5 07	1 23	9 39	18 85	42 92
128-169	0	0	0 21	0 31	1 64
170-193	0	0	0 03	0	0 02
194-205	0	0	0	0	0
206-208	0	0	0	0	0
	Aroclor1254[a]	Aroclor 1254[b]	Aroclor 1260	Aroclor 1262	Aroclor 1268
1-3	0 02	0	0 02	0 02	No data
4-15	0 09	0 24	0 08	0 27	No data
16-39	0 39	1 26	0 21	0 98	No data
40-81	4 86	10 25	0 35	0 49	No data
82-127	71 44	59 12	8 74	3 35	No data
128-169	21 97	26 76	43 35	26 43	No data
170-193	1 36	2 66	38 54	48 48	No data
194-205	0	0 04	8 27	19 69	No data
206-208	0 04	0 04	0 70	1 65	No data

Source ATSDR 2000

[a] Lot A4 Aroclor 1254 (Monsanto Lot KI-02-6024) from abnormal late production (1974–1977)

[b] Lot G4 Aroclor 1254 (GE/118-peak analytical standard)

7

Table 3 Weight Percent of Congeners in Various PCB Mixtures

BZ #	Aroclor Composition (Wt %)						
	A1016	A1242	A1248a	A1248g	A1254a	A1254g	A1260
1	0 52	0 54	0 05	0 02	0 02		0 02
2	0 02	0 03					
3	0 15	0 18	0 01				
4	3 62	3 08	0 32	0 04	0 02	0 06	0 02
5	0 17	0 14	trace				
6	1 64	1 43	0 13	trace	0 01	0 02	0 01
7	0 29	0 26	0 02				
8	8 29	7 05	0 81	0 26	0 05	0 13	0 04
9	0 58	0 5	0 04				
10	0 23	0 2					
11							
12	0 07	0 06					
13	0 24	0 22	0 02				
14							
15	2 4	2 1	0 22	0 06	0 01	0 03	0 01
16	3 88	3 14	1 04	0 71	0 02	0 09	0 01
17	3 98	3 13	1 05	0 93	0 02	0 08	0 02
18	10 86	8 53	4 29	3 29	0 08	0 25	0 05
19	0 99	0 8	0 22	0 14			
20	0 88	0 72	0 14	0 08			
21							
22	3 5	2 84	1 33	1 38	0 02	0 04	0 01
23	0 01	0 01		trace			
24	0 16	0 13	0 01				
25	0 72	0 59	0 11	0 04			
26	1 57	1 28	0 4	0 23		0 03	
27	0 51	0 41	0 12	0 07			
28	8 5	6 86	3 59	5 57	0 06	0 19	0 03
29	0 1	0 08	trace	0 01			
30	trace						
31	9 32	7 34	5 07	5 47	0 11	0 28	0 04
32	2 37	1 9	0 88	0 93	0 01	0 05	0 01
33	6 21	5 01	2 23	2 21	0 05	0 16	0 03
34	0 03	0 02	trace	trace			
35	0 05	0 08	trace				
36							
37	1 02	2 03	0 79	0 95	0 01	0 07	0 01
38							
39							
40	0 58	0 76	1 13	0 92	0 15	0 12	
41	0 76	0 68	0 77	0 75	0 02	0 01	
42	1 59	1 19	1 67	1 79	0 09	0 15	0 01
43	0 28	0 18	0 3	0 19			

8

BZ #	Aroclor Composition (Wt%)						
	A1016	A1242	A1248a	A1248g	A1254a	A1254g	A1260
44	4 47	3 55	6 31	5 09	0 67	2 31	0 03
45	1 23	0 89	1 09	0 91	0 02	0 05	
46	0 49	0 36	0 47	0 39			
47	1 26	0 93	1 49	2 41	0 07	0 14	
48	1 61	1 18	1 66	1 54	0 05	0 12	
49	3 35	2 53	4 12	4 17	0 26	1 1	0 01
50	0 01	trace					
51	0 32	0 23	0 3	0 31			
52	4 63	3 53	6 93	5 58	0 83	5 38	0 24
53	0 95	0 71	1 05	0 88	0 04	0 12	
54	0 01	0 01		0 01			
55		0 1	0 06	0 05			
56	0 07	1 81	3 16	3 19	1 7	0 55	0 02
57	0 01	0 02	0 02	0 02			
58							
59	0 41	0 32	0 37	0 23	0 01	0 02	
60	0 04	1 18	1 85	2 67	0 95	0 18	0 04
61							
62							
63	0 06	0 12	0 17	0 19	0 07	0 02	
64	1 87	1 7	3 01	3 32	0 36	0 59	0 01
65							
66	0 39	3 39	5 84	7 22	3 56	1 01	0 02
67	0 06	0 16	0 13	0 1	0 01		
68							
69	trace						
70	0 59	3 73	7 28	7 39	6 83	3 49	0 04
71	1 16	1 03	1 67	1 86	0 11	0 15	0 01
72	trace	0 01	0 02	0 01			
73	trace	trace					
74	0 33	1 81	3 14	4 67	2 19	0 84	0 05
75	0 06	0 04	0 08	0 08			
76		0 08	0 13	0 13	0 03	0 02	
77		0 31	0 41	0 52	0 2	0 03	
78							
79							
80							
81		0 01	0 01	0 02	trace		
82		0 26	0 81	0 62	1 53	1 11	
83		0 11	0 26	0 2	0 56	0 48	0 01
84	0 05	0 41	1 26	0 91	1 58	2 32	0 11
85		0 31	0 98	1 14	2 49	1 28	0 01
86		0 03	0 11	0 09	0 1	0 06	
87		0 46	1 45	1 11	3 41	3 99	0 41

BZ #	Aroclor Composition (Wt.%)						
	A1016	A1242	A1248a	A1248g	A1254a	A1254g	A1260
88		trace	0 02	0 02			
89		0 09	0 2	0 17	0 11	0 09	
90							
91	0 06	0 21	0 63	0 56	0 53	0 93	0 01
92		0 09	0 38	0 25	0 57	1 29	0 3
93		trace	0 04	0 03			
94		0 01	0 03	0 02	0 01	0 02	
95	0 31	0 61	1 96	1 43	1 84	6 25	2 45
96	0 04	0 03	0 08	0 06	0 01	0 04	
97		0 38	1 22	0 97	2 78	2 62	0 09
98							
99	0 01	0 46	1 47	1 81	4 53	3 02	0 04
100							
101	0 04	0 69	2 22	1 89	5 49	8 02	3 13
102	0 04	0 07	0 19	0 17	0 09	0 15	
103			0 02	0 01		0 03	
104							
105	trace	0 47	1 6	1 45	7 37	2 99	0 22
106							
107		0 06	0 18	0 13	0 78	0 37	0 01
108							
109							
110		0 83	2 97	2 55	8 42	9.29	1 33
111							
112							
113					0 01		
114		0 04	0 12	0 12	0 5	0 18	
115		0 04	0 11	0 11	0 37	0 2	
116							
117		0 03	0 09	0 1	0 19	0 23	
118		0 66	2 29	2 35	13 59	7 35	0 48
119			0 06	0 06	0 12	0 08	
120							
121							
122		0 01	0 06	0 05	0 25	0 1	
123		0 03	0 07	0 08	0 32	0 15	
124		0 03	0 1	0 07	0 47	0 29	0 01
125		0 02	0 04	0 03	0 03	0 02	
126			trace	trace	0 02	trace	
127							
128		0 02	0 12	0 08	1 71	1 42	0 53
129			0 02		0 39	0 38	0 14
130			0 04	0 01	0 5	0 6	0 22
131					0 14	0 19	0 07

10

BZ #	Aroclor Composition (Wt%)						
	A1016	A1242	A1248a	A1248g	A1254a	A1254g	A1260
132		0 04	0 15	0 14	1 5	2 29	2 9
133						0 11	0 07
134				0 01	0 2	0 37	0 34
135			0 04	0 04	0 28	0 61	1 08
136			0 05	0 06	0 24	0 7	1 46
137			0 03	0 02	0 52	0 42	0 02
138		0 1	0 38	0 41	5 95	5 8	6 54
139					0 14	0 15	
140							
141		0 01	0 07	0 09	0 69	0 98	2 62
142							
143							
144				0 01	0 12	0 24	0 61
145							
146			0 04	0 05	0 45	0 67	1 15
147					0 02	0 1	
148							
149		0 06	0 24	0 33	1 82	3 65	8 75
150							
151			0 04	0 08	0 22	0 69	3 04
152							
153		0 06	0 23	0 43	3 29	3 77	9 39
154					0 02	0 04	
155							
156		0 01	0 06	0 04	1 13	0 82	0 52
157			0 01	trace	0 3	0 19	0 02
158		0 01	0 04	0 04	0 9	0 81	0 58
159							
160							
161							
162							
163		0 01	0 06	0 08	0 7	1 03	2 42
164			0 02	0 03	0 31	0 4	0 69
165							
166					0 05	0 05	
167			0 01	0 01	0 35	0 27	0 19
168							
169							
170				0 08	0 35	0 52	4 11
171					0 08	0 14	1 11
172					0 03	0 07	0 7
173							0 1
174				0 08	0 14	0 34	4 96
175							0 17

11

BZ#	Aroclor Composition (Wt %)						
	A1016	A1242	A1248a	A1248g	A1254a	A1254g	A1260
176					0 01	0 04	0 59
177				0 03	0 08	0 2	2 57
178						0 03	0 83
179				0 02	0 02	0 1	2 03
180			0 02	0 21	0 42	0 67	11 38
181							0 01
182							
183				0 06	0 09	0 18	2 41
184							
185							0 55
186							
187				0 09	0 09	0 25	5 4
188							
189					0 01	0 01	0 1
190					0 05	0 07	0 82
191							0 17
192							
193						0 03	0 53
194						0 01	2 07
195							0 84
196							1 09
197							0 07
198							0 1
199						0 01	1 78
200							0 25
201							0 24
202							0 33
203						0 02	1 4
204							
205							0 1
206					0 03	0 03	0 53
207							0 05
208					0 01	0 01	0 13
209							

12

Table 4 TEFs for PCB Congeners

PCB Congener	TEF
77	0 0001
81	0 0001
105	0 0001
114	0 0005
118	0 0001
123	0 0001
126	0 1
156	0 0005
157	0 0005
167	0 00001
169	0 01
189	0 0001

13

14

Table 5 Congener and TEQ Concentrations in Aroclor Mixtures

		A1016	A1016	A1242	A1242	A1248a	A1248a	A1248g	A1248g	A1254a	A1254a	A1254g	A1254g	A1260	A1260
PCB Congener	**TEF**	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*	*C (ppt)*	*TEF X C (ppt)*
PCB-77	0 0001	0	0	31000	3 1	41000	4 1	52000	5 2	20000	2	3000	0 3	0	0
PCB-81	0 0001	0	0	1000	0 1	1000	0 1	2000	0 2	100	0 01	0	0	0	0
PCB-105	0 0001	100	0 01	47000	4 7	160000	16	145000	14 5	737000	73 7	299000	29 9	22000	2 2
PCB-114	0 0005	0	0	4000	2	12000	6	12000	6	50000	25	18000	9	0	0
PCB-118	0 0001	0	0	66000	6 6	229000	22 9	235000	23 5	1E+06	135 9	735000	73 5	48000	4 8
PCB-123	0 0001	0	0	3000	0 3	7000	0 7	8000	0 8	32000	3 2	15000	1 5	0	0
PCB-126	0 1	0	0	0	0	100	10	100	10	2000	200	100	10	0	0
PCB-156	0 0005	0	0	1000	0 5	6000	3	4000	2	113000	56 5	82000	41	52000	26
PCB-157	0 0005	0	0	0	0	1000	0 5	100	0 05	30000	15	19000	9 5	2000	1
PCB-167	0 00001	0	0	0	0	1000	0 01	1000	0 01	35000	0 35	27000	0 27	19000	0 19
PCB-169	0 01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PCB-189	0 0001	0	0	0	0	0	0	0	0	1000	0 1	1000	0 1	10000	1
TEQ			**0 01**		**17**		**63**		**62**		**512**		**175**		**35**

C – Concentration based on an Aroclor concentration of 10 ppm
ppt – parts per trillion

Table 6 Concentrations of Chlorinated Dibenzofurans (CDFs) in Commercial Polychlorinated Biphenyl Mixtures[a]

PCB	Tetra-CDF	Penta-CDF	Hexa-CDF	Total (PCDFs)[b]
Aroclor 1016 (1977)	ND	ND	ND	--
Aroclor 1016)	ND	ND	ND	--
Aroclor 1242	0 07	0 03	0 003	0 15
Aroclor 1242	0 07	0 03	0 003	0 15
Aroclor 1242	2 3	2 2	ND	4 5
Aroclor 1254 (1969)	0 1	0 2	1 4	1 7
Aroclor 1254 (1970)	0 2	0 4	0 9	1 5
Aroclor 1254	0 02	0 2	0 4–0 6	0 8
Aroclor 1254	0 1	3 6	1 9	5 6
Aroclor 1260 (1969)	0 1	3 6	1 9	5 6
Aroclor 1260 (Lot AK3)	0 2	0 3	0 3	0 8
Aroclor 1260	0 3	1 0	1 1	3 8b
Aroclor 1260	0 8	0 9	0 5	2 2

Source ATSDR 2000
[a] in ppm
[b] Total includes quantities of tri- CDF and hepta-CDF isomers that were analyzed
CDF = chlorodibenzofuran,
PCDFs = polychlorinated dibenzofurans

15/15